1 Introduction

In hospital and health care system management, one of the critical points is the lack of indicators similar to those used in other traditional environments such as factories (Bracale et al., 1983).

This lack is typical of the caring professions which, in offering health services, have objective difficulty in expressing quantitatively the 'state of health' as an output of their activity. Nevertheless, there are in health care systems other administrative and managerial parameters similar or equivalent to those used in other kinds of traditional activities.

For planning or co-ordinating health services it is necessary to have reference points for evaluating similar departments in which homogeneous or equivalent activities are carried out. It is also necessary to consider the cost/benefit of the services. The paper presents several new indices of performance which may be applied to this problem and which enable quantitative comparisons to be made between hospitals and between departments. These indices include assessment of electrical hazards and service ability of equipment as well as the ratio of technical support staff to inpatient-stay. The indices have been evaluated in a few large hospitals and found to be an effective management tool.

Keywords - Clinical engineering, Cost/benefit analysis, Medical equipment maintenance

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For planning or co-ordinating health services it is necessary to have reference points for evaluating similar departments in which similar or equivalent activities are carried out (Zanetti et al., 1976). The difficulties are further increased by the growing use of medical equipment, which on one hand may contribute to the 'efficiency and efficacy' of the health services but on the other hand increases the complexity of the problem financially as well as from an organisational point of view (Irnich and Miethe, 1984; Shaffer, 1985).

The concept of the 'number of beds', which in the past was routinely used as a useful indicator of activity, is at present often meaningless: for example it is impossible to compare the beds of an obstetrical department with those of an intensive care unit as a reference point in planning or for financial considerations.

In other cases, it may be interesting to compare the activities of similar departments (e.g. orthopaedic surgery) to understand financially what produces a different mean time for patient stay. In this case it is necessary to define some further indicator.

The Biomedical Department at Naples University is involved in a program of clinical engineering, carried out under a special project with the Consorzio Regionale Farmaceutico Ospedaliero (CRFO) in Naples. In this project the main goal is to investigate the state of the art of preventive maintenance, repair work and safety of biomedical diagnostic, monitoring or therapeutic devices and general equipment.

This research has been developed in four hospitals in Naples:

(a) Antonio Cardarelli: 3500 beds with 58 departments
(b) Centro Traumatologico Ospedaliero: 300 beds with 16 departments
(c) Elena d'Aosta: 200 beds with nine departments
(d) San Paolo: 330 beds with 12 departments.

An inspection of departments, equipment and general facilities was carried out as a precursor to preparing a comparison between different departments in the same hospital, and between different hospitals. The difficulties mentioned above were a barrier to conclusive practical recommendations. Indeed, it was felt that many of the previous attempts at computerising equipment records (Johnston, 1983; Kresch et al., 1985; Langston, 1983; Nippa, 1983; Schwartz, 1983) were inappropriate for the problems facing us.

Accordingly, the activity of clinical engineering was considered with a more general aspect of health care systems evaluation, trying to define some indices for evaluating the 'state of the health service' under investigation. In the present paper the general organisation of the database realised is described; then the definitions and the relation-
ships between the different indices are described, and finally some examples of the system used and experimental results are reported. A computer was used for the management of information.

2 Computerised data system for management of hospital information

The information system was developed on a Hewlett Packard 1000 E series system with 256 kbyte of main memory. Two Mbyte hard disks serve as the main mass storage device. In addition the system has two tape cartridges connected with one of two video terminals and a photoreader. The computer is run under RTE IV B, a real-time multiprogramming system, supporting some video terminals running at 9600 baud. An HP 2631 B dot matrix printer is the main printer system.

The database was designed using structural analysis (SA) (Ross and Shoman, 1977) and entity relationship (ER) methodology (Ceri, 1983). The SA methodology performs the formulation and analysis of the requirements, and provides a hierarchic, top-down, gradual exposition of detail in the form of an SA model. The environmental requirements are expressed in a data decomposition and an activity decomposition. In this model the user problem is represented by a box on the top of the hierarchic model (see Fig. 1). The box is divided into at least three and not more than six boxes. The ‘top box’ is called ‘father’, the lower one is called ‘son’. The boxes on the same level are united by arrows which stand for the input, output and checks. In the activity diagram the boxes represent the ‘activities’ and the arrows represent ‘the data’. In the data diagrams the boxes represent ‘the data’ and the arrows, the ‘activities’.

The outputs on the SA are the input of the ER methodology. The entity relationship model allows a data schema of all data used by the operators of a particular environment to be established. In the present model we have three basic classes of objects: entities, attributes and relationships. The entities are a particular information aggregate specified in the requirements. Entities could be described by attributes that contain detailed information about the entity and one or more of which might serve as an identifier to distinguish different entities.

Relationships between entities depict the functional aspects of the information represented by the entities.

The best approaches to forming well structured entity diagrams encompass the four basic design decisions (or steps):

(a) selection of entities
(b) selection of entity attributes
(c) identification of key attributes for entities
(d) selection of relationships between entities.

![Fig. 2 Entity relationship model](image)

The output of this phase is the logical scheme of Fig. 2, which was converted into a physical scheme to be used as an input for the database management system (Image 1000 DBMS).

The database in its present form could support a variety of management needs of hospital, department and electro-medical equipment (inventory, safety recalls, life-cycle cost, repair history, planning etc.) and with a little expansion could support preventive maintenance management.

The proposed model of the database should address some aspects of the hospital, department and electro-medical equipment.

(a) for the hospital:
   - general information including name, address and USL (Local Health Unit)
   - structure and employees, including information on the number of beds and power supply

(b) for the hospital department: (Fig. 3)
   - general information
   - structure and employees
   - power supply

(c) for the electromedical equipment: (Fig. 4)
   - inventory information, including descriptive information, acquisition data
   - technical performance information, including the electrical safety criteria, power supply
   - information on accessories
   - life-cycle cost information
   - information on repairs.

In considering the database structure the two broad categories of organisation user can be identified as hospital administration and the technical staff.

The database procedure was written in Fortran 4 with a DBMS (database management system) call extension. The main program, or the first program to be executed, displays the main menu, which is composed of:

(i) data input
(ii) report
(iii) search
(iv) update
(v) exit.